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THE ROLE OF VISUALS IN VERBAL LEARNING. STUDIES IN TELEVISED INSTRUCTION. AN INTERIM REPORT.
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AN EXPERIMENT TO DETERMINE EFFECTIVENESS OF VISUAL (VI) AND VERBAL (VE) PROGRAMED PRESENTATIONS ALSO VARIED RESPONSE MODE (ACTIVE VERSUS PASSIVE) AND ORDER OF PRESENTATION OF VI AND VE VERSIONS OF A SCIENCE LESSON FOR 200 GRADE 8 STUDENTS, TAUGHT VIA CLOSED CIRCUIT TELEVISION. THE FACTORIAL DESIGN REQUIRED EXPOSURE TO ONE LESSON VERSION, IMMEDIATE POST TEST, A BRIEF BREAK, AND EXPOSURE TO EITHER THE SAME OR THE ALTERNATE LESSON VERSION, ALSO FOLLOWED BY AN IMMEDIATE POST TEST. ANALYSIS OF GAIN SCORES BASED ON PRE-, IMMEDIATE POST-, AND DELAYED ACHIEVEMENT TESTS (WITH BOTH VI AND VE ITEMS) SHOWED SIGNIFICANT GAINS FOR--ACTIVE RESPONSE TO THE VI-VE ORDER, TYPE OF TEST ITEM AND THE CORRESPONDING LESSON VERSION, AND LESSONS VIEWED IN THE VI-VE ORDER. (LH)

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Studies in Televised Instruction

THE ROLE OF VISUALS IN VERBAL LEARNING

AN INTERIM REPORT

George L. Gropper

August 1962

Metropolitan Pittsburgh
Educational Television Station
and the
American Institute for Research

PITTSBURGH, PENNSYLVANIA

FOREWORD

The research described in this interim report was made possible by a Title VII grant under the National Defense Education Act of 1958, grant number 7-36-120. The title of the project is: "Instructional Techniques for Improving Student Understanding of Principles Illustrated in Televised Science Demonstrations." Accomplishments to date reflect contributions made by a number of people including: Arthur A. Lumsdaine who provided critical comments during planning phases of this project; Ronald Ernst who helped in the development of experimental materials; David J. Klaus and Margaret Samways who provided editorial comment on programmed verbal materials used in this project; Harris H. Shettel who provided editorial comment on programmed visual materials used in this project; and, particularly, Robert Glaser who provided critical comment during all phases of the project and who reviewed a draft of this report.

This interim report provides a preliminary account of an initial experiment on the programming of visual demonstrations. It also provides some tentative, more general considerations on the role of visuals in verbal learning. Final reports will continue this discussion in more complete detail as well as describe the results of additional experiments suggested by it.

George L. Gropper
August 1962

ABSTRACT

Preliminary proposals have been offered concerning the role that visuals might play in facilitating student understanding of verbal concepts. Two contrasting uses of visuals designed to achieve that objective were described: First, visuals can be used to cue and to reinforce verbal responses. In this manner, verbal responding can be brought under the explicit control of visual stimuli, thereby facilitating student acquisition of a verbal repertoire. Second, visuals can also be used to provide for explicit control over student practice of visual discriminations. Programmed visual demonstrations can require the practice of appropriate visual discriminations that lead to student acquisition of abstract concepts.

An experiment was conducted to assess the feasibility and effectiveness of this second approach. A purely visual demonstration on Archimedes' Law was programmed. A purely verbal lesson on the same lesson content was also programmed. Seventh and eighth grade students saw both versions of the lesson over closed-circuit TV with different groups seeing the two versions in different orders. Active and passive versions of both lessons were also used.

Preliminary results for this experiment were based on achievement test scores obtained on tests administered: (a) immediately after students saw either the visual or the verbal lesson; (b) immediately after students saw both versions, with the order of presentation varying among groups; and (c) on a delayed basis about two to three weeks later. Results were as follows:

1. Visual vs. Verbal Programs

    -- students who watched either the visual program or the verbal program made significant gains in achievement; both groups made gains of approximately 25%; on the total test score there was no significant difference between these two groups.

-- on visual or pictorial items on the test, the group which had watched the visual program made gains of 25% as against the 10% made by the group which had watched the verbal program.

-- on the verbal items in the test, high IQ students in the verbal group made gains of 37% as against gains of only 19% made by high IQ students in the visual group.

2. Visual/Verbal vs. Verbal/Visual Order

-- students who watched both lessons in the visual/verbal order made gains on total test scores of approximately 40% as against only 22% for students who saw both lessons in the reverse order.

3. Active vs. Passive Response

-- among students who saw both lessons in the visual/verbal order, those who viewed the active response version made and retained significantly higher gains on achievement test scores than did those who viewed a passive version. On the verbal items of the delayed test, the active response group made gains of approximately 65% as against only 20% made by the passive response group.

The results of this experiment were judged to be indicative of the feasibility and desirability of programming visual demonstrations. Further discussion was offered on the nature of the optimum integration of verbal and visual material in demonstrations.

INTRODUCTION

The objectives of education which require students to be able to recognize and recall facts or to understand principles or concepts call for behaviors that are essentially verbal in nature. The acquisition of knowledge in most academic subjects may be said to consist in the acquisition of a repertoire of such verbal responses. The criterion performance expected of the student typically consists of his ability to provide a verbal response to such verbally posed questions as: "What is the capital of Japan?", "Who wrote the 'Wealth of Nations'?", or "What are finite numbers?". Both question and answer (or stimulus and response) belong to the same mode, namely, the verbal mode.

Instruction in science, like instruction in most other academic subjects, also seeks to build up a verbal repertoire which can be elicited by verbally posed questions. The student may be expected to answer such questions as: "What is the specific gravity of alcohol?", "What happens to solid objects when they are heated?", or "What is the Bernouilli effect?". Instruction in science differs from instruction in other subject matters, social studies or languages, for example, in that students are also expected to provide verbal explanations for <u>visually perceived</u> physical phenomena. Here, stimulus and response terms belong to different modes.

The identity or non-identity of modes for stimulus and response terms raise a number of important issues which apply not only to science instruction. They apply also to other subject matters which, although essentially verbal in nature, nevertheless use non-verbal, pictorial aids to build up verbal repertoires. These issues underlie but have rarely been made explicit in much of the research that has been done on the use of words and pictures in instruction. Recently reviewed by Hartmann (1), research on words vs. pictures has been shown to have had a long history. This research has not, however, addressed itself to the explicit question concerning the similar or possibly contrasting roles that words or pictures might play in shaping verbal behavior. Rather, it has addressed itself to the relatively undifferentiated question of which teaches more effectively -- words or pictures. Thus, this type of research does not provide systematic or analytic answers to questions about the proper role of words and pictures in attaining particular kinds of educational objectives.

In the more limited context of paired-associate verbal learning, however, Lumsdaine (2) and Kopstein and Roshal (3) have led the way toward a more analytic approach by investigating the relative effectiveness of words and pictures in the stimulus and response positions. Their results indicate the superiority of pictures in the stimulus position and words in the response position. Similar analytic studies on the role of words and pictures in connected-discourse verbal learning, as in learning history or physics for example, remain to be conducted. The role and value of demonstrations in science instruction or of visual aids in other subject matters can be properly assessed only when characteristics of visuals and the functions visuals can play in verbal learning are fully identified.

Some of the issues underlying the use of visuals will be explored in brief and preliminary fashion in this interim report. A description will also be given of progress to date on research currently underway which seeks to provide empirical data on some of these issues. Final reports in this series will provide a more detailed analysis and will present the experimental evidence bearing on problems briefly raised here.

ROLE OF THE VISUAL

An analysis of the role visuals can play in verbal learning must concern itself with the characteristics of visuals which promote effective conditions of learning. Visuals may thus be characterized in terms of their differential capacity to facilitate the acquisition, retention, or transfer of verbal responses. Variations in this capacity may be said to arise from the differential effectiveness with which visuals are used to serve as cue, discriminative stimulus, or reinforcer. It is in serving these customary learning functions that visuals can play a role in verbal learning.

LEARNING FUNCTIONS SERVED BY VISUALS

Through associative learning verbal responses become attached to visually perceived, physical objects or events. Visual stimuli can, thus, acquire the capacity to elicit the particular verbal responses with which they have become associated. Based on such past associative learning, visual stimuli may be employed to facilitate new learning through their capacity to elicit the already available verbal responses. Once elicited these responses may then be recombined in new arrangements or be attached to new stimuli. In the course of instruction, it is often important to bring about such associations between available verbal responses and new visual stimuli. Two circumstances in which this would be the case are: (a) when, as in science instruction, the criterion situation consists of physical situations to which verbal responses are to be attached (i.e., when the student is expected to describe or interpret physical phenomena); or (b) when, based either on learning or logistical considerations, it is efficient to create visual-verbal associations in order to bring about still other, perhaps more complex associations (as, for example, when it might appear desirable to explain a specific event before going on to a generalization about classes of events).

The "meaning" physical objects and events have can be defined in terms of the verbal responses with which they have in the past become associated and which they are now capable of eliciting in either overt or covert form. It is in this sense that the "meaning" of visually perceived objects and events may be used to facilitate learning. Visual stimuli not only have the capacity to cue particular verbal responses, but based on their meaning to students, can also reinforce (provide confirmation for) responses they make. If during instruction students are required to make verbal responses predicting the outcome of physical events, the physical events themselves can confirm the correctness of those responses. Thus, when the verbal response to be made by students is "boils", water actually coming to a boil may serve a confirmation function similar to that provided by the printed or oral statement "boils" or by the verbal statement "correct." (It may be that, in both the confirmation sense and in the motivational sense, reinforcement by visual means may be more effective than telling a student he is right or giving him the correct response with which he may then compare his own response. The comparability (or lack of it) among these modes of confirmation can, it seems plausible, be readily assessed by direct experimental confrontation.)

Because physical objects and events have meaning or acquire meaning for students, they can, in addition to serving as cues and as reinforcers, also serve as discriminative stimuli. Physical situations may provide the context within which other stimuli, whether verbal or non-verbal, serve either as cues or as reinforcers. So, for example, a science demonstration may serve as the occasion for students practicing responses other than the responses directly associated with the events in the demonstration. A specific demonstration of the expansion of either a gas, liquid, or solid, might serve as an appropriate context for the practice of, but obviously not the cue for, the more abstract response: "all matter expands when heated."

It appears important that research be conducted to determine: (a) under what conditions and for what verbal learning objectives visuals are to be preferred over words to serve as cues, reinforcers, or discriminative stimuli; and (b) what the properties of visual stimuli are that make them effective as cues, reinforcers, or discriminative stimuli in verbal learning.

POTENTIAL ADVANTAGES IN THE USE OF VISUALS

Visuals possess properties which potentially can enhance their cuing or reinforcement functions. Some of the same properties may also be capable of reducing time requirements which can make instruction more efficient. Brief and preliminary considerations about a half-dozen of these properties and the advantages they promise now follow:

1. Sampling Visual Criterion Elements

Since transfer is facilitated when similar elements are shared in both the learning and the criterion situations, it appears desirable that the visual stimuli which will ultimately be experienced in the criterion situation be employed in the learning situation whenever possible. In those subject matters, such as physics for example, where the physical objects and events which are to be described or explained verbally are integral parts of the criterion situation, there are obvious advantages to employing those objects and events (or representations of those objects and events) in the learning situation.

2. Making the Unobservable Observable

In science there are unobservable phenomena which must be described, explained, or interpreted. It is possible by means of visual representations of an indirect, analogous, or arbitrary nature to present physical observable models for those phenomena. The availability of such models may facilitate student practice of appropriate verbal responses elicited and/or reinforced by properties of the visual model.

3. Making the Abstract Concrete

Both in science and in other subject matters there are abstract concepts and relationships which have no physical referents. As in the case of unobservable phenomena, it is possible through visual representations to make the abstract concrete, primarily by analogous or arbitrary models. If it is true, as is popularly believed, that it is easier to learn from concrete than from abstract materials, this advantage would derive from the fact that the "concrete" may outperform a verbal abstraction as a cue, reinforcer, or discriminative stimulus.

4. Increasing the Span of Apprehension

Visual presentations appear to be more efficient than verbal presentations in that they are capable of presenting more assimilable information in a unit of time than can be presented in verbal terms. If this more dense visual presentation has high associative strength with the particular verbal responses to be elicited (and not with other potentially competing responses), it would seem to be preferable to a verbal presentation, if only from a logistical point of view.

5. Simplifying the Complex

Not only can a visual presentation convey more information in a unit of time, it can also accomplish the opposite. What is often difficult or complex to describe in words can be made more readily accessible in visual terms through simplification. The amount of information presented in a unit of time may be reduced and made more assimilable through the use of appropriate visual models.

6. Focusing on the Relevant

Through such pointing techniques as labeling or restricting the visual field or through such distortion techniques as simplification or exaggeration, it is possible to focus attention on relevant features of a physical situation. The cue-value of physical stimuli may be enhanced through the use of such techniques.

Many of these advantages that visuals possess derive from the fact that in addition to standing for or representing themselves they can stand for or represent other phenomena. Thus, an observable model may stand for unobservable phenomena. A concrete visual may stand for an abstract concept or a simplified visual can stand for a complex physical or conceptual relationship.

Visuals can stand for or represent physical phenomena and also verbal statements about those phenomena. They can also stand for or represent verbal statements that have no concrete referent. Since visuals can represent such a variety of referents, it appears likely that the types of relationships between visual and referent are highly diverse. If visuals are to serve useful functions in facilitating verbal learning, it is important that the nature of the relationship between visuals and the referents they are intended to represent be treated more systematically.

NATURE OF VISUAL REPRESENTATION

One major dimension along which the relationship between visual and referent may vary can be called "literalness." By literalness is meant the extent to which the visual representation reproduces or reconstructs in physical terms the referents denoted in a verbal proposition. Verbally described physical objects and events can be literally paralleled in physical terms. Abstractions, however, cannot be similarly paralleled, but they are still susceptible of representation in non-literal physical terms.

The dimension of literalness can be further explicated by a description of the following four types of visual representation:

Direct Representation: It is often desirable to represent directly in visual terms something that has been stated verbally. So, for example, in science instruction it might be helpful to demonstrate in visual terms the physical phenomenon of a bending bi-metal bar described by the verbal statement, "the bi-metal bar bends as it is being heated." The bending of a bi-metal bar is actually shown occurring following the application of heat to it. The visual demonstration or representation literally reproduces or reconstructs what is referred to in the verbal statement or proposition. Thus, visual and verbal presentation in this instance directly parallel one another. No further words are needed to connect the visual events and what is denoted by the verbal proposition.

Indirect Representation: Sometimes when the referent described in a verbal proposition is a physical event that is unobservable or when the referent is an abstraction, we often rely on indirect visual representation. Indirect visual representations can be used in the following situations: (1) where the physical referent (in a verbal proposition) is unobservable, it may be indirectly represented through results or effects; for example, the amount of expansion which solids undergo upon being heated is minute and not observable to the naked eye; a ball and ring experiment, in which a heated ball no longer passes through a ring, might be used to represent the expansion phenomenon; here, however, what is being represented is the inability of the ball to be extracted from the ring following the application of heat to it; thus it is the effect of expansion which is being represented directly; the expansion itself is only indirectly represented; (2) similarly, general principles cannot themselves be directly represented; they can, however, be indirectly represented through specific instances; for example, the general proposition "all matter expands when heated" cannot be directly represented; but a specific instance of a gas or a liquid expanding can be demonstrated and these demonstrations then serve as indirect visual representations of the more general verbal proposition; (3) abstract ideas also cannot be directly represented but can be adequately represented indirectly by concrete instances; in talking about charity, to use a non-crete example, scenes of material help being given to needy persons can be presented visually.

In all three instances cited above where the verbally described referent is unobservable, is a generalization, or is abstract, indirect visual representations can be used. However, the visual does not directly reconstruct or reproduce the verbal statement we wish to get across. The visual does not parallel the verbal statement. By itself, the visual represents this statement only indirectly. Further words are therefore needed to establish the connection between the visual and what is denoted by the verbal statement.

Analogous Representation: Another way verbally described referents that cannot be directly (or even indirectly) represented can be represented is by means of analogy. Other physical and visually perceived phenomena which operate in analogous fashion or have analogous properties can be used to represent the phenomena under consideration. "Electromotive force," for example, cannot itself be directly or literally represented. We may, however, use a hydraulic system which operates in analogous fashion to represent it. Most graphic illustrations, such as curves or bar charts are analogous representations. Physical variations in the visual representations are analogous to variations in the phenomena to be represented. So, for example, the pie chart is made up of areas of varying size that are proportional to the phenomena that are represented by it. In analogous representation, further verbal commentary is needed to establish the connection between the phenomena presented in visual terms and the original phenomena to be described or explained verbally.

Arbitrary Representation: There are many occasions when short-hand visual representations are desired for referents which may or may not be capable of direct, indirect, or analogous representation. Phenomena such as symbols or visuals which bear no physical or even logical relationship to the referent can nevertheless be used to represent it. The representation is arbitrary and is established by convention only. The symbol X may stand for the amount of rainfall in India; or the barber pole can stand for the barber shop; or a crest may stand for a family; a balance scale can stand for the abstract idea of "justice," etc.

The capacity of visual representations to serve as cues, discriminative stimuli, or reinforcers in shaping a particular verbal repertoire will be undoubtedly influenced by the literalness of those representations. It seems clear that when the visual literally parallels the verbal proposition to be acquired and has high associative strength for that verbal proposition, it can serve effectively and efficiently in facilitating the practice of appropriate responses. Where the visual is a non-literal representation, it may be used to cue or reinforce verbal responses other than the ones to be acquired. This does not mean that its use will be ineffective. What it does mean is that it will have to serve as part of an intermediate step in reaching the ultimate behavior to be acquired. It therefore appears important in instructional situations employing visual aids that close, analytic attention be paid to the nature of the relationship between referent and visual representation.

Some of the problems involved in using visual representations of varying degrees of literalness have already been uncovered during the course of an experiment already conducted for this project. In that experiment, an entirely visual lesson was programmed (in the teaching machine sense) to determine just how far a visual alone could go in generating verbal concepts. A description of this effort will be useful in clarifying some of the issues involved in relationships between referents and their visual representation.

EXPERIMENT #1

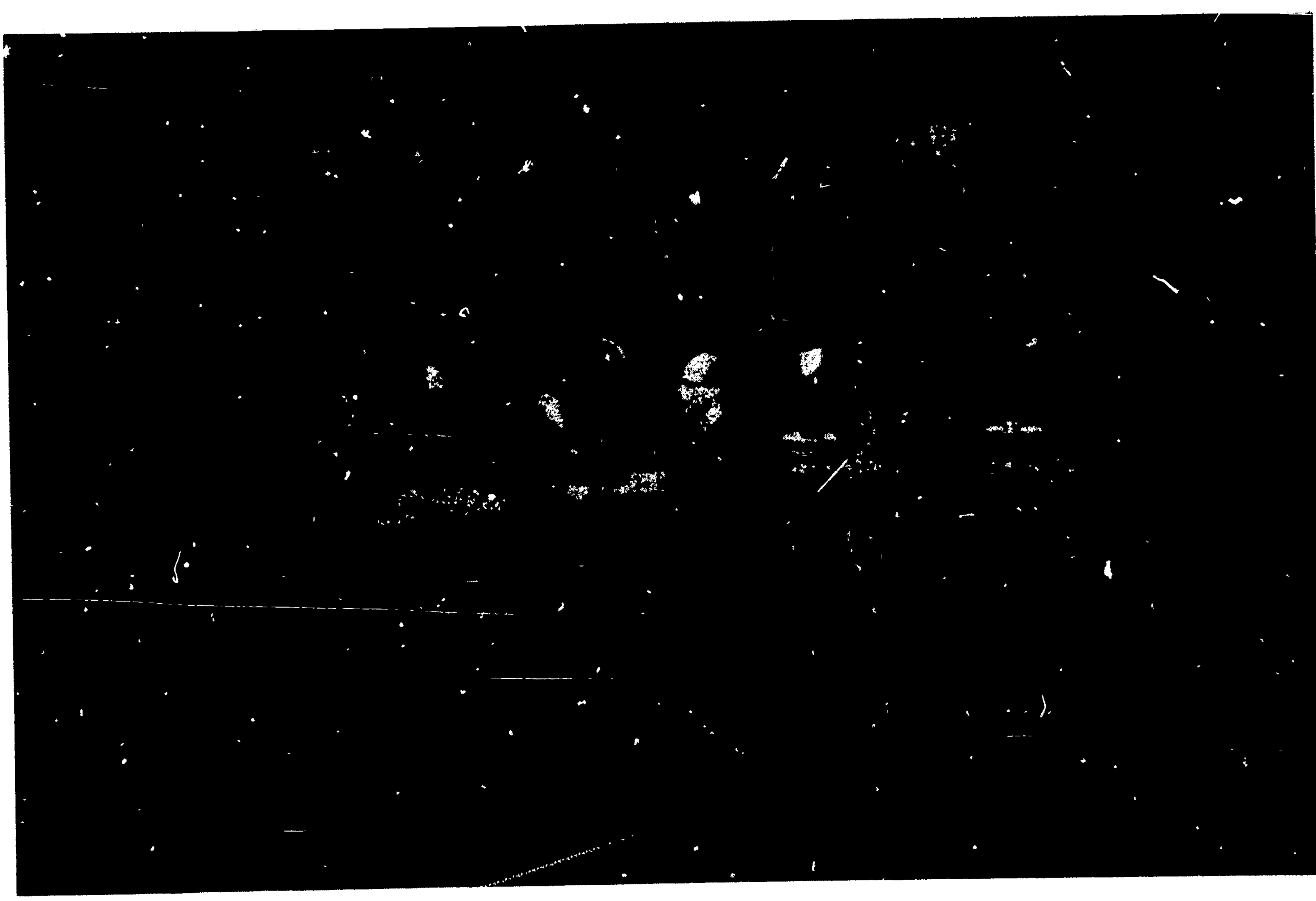
an experimental study of the:

-- feasibility of programming visual demonstrations

-- relative effectiveness of visual and verbal programs

-- optimum sequence of visual and verbal programs

-- differential effectiveness of active and passive responding



EXPERIMENTAL EVALUATION OF VISUAL AND VERBAL PROGRAMS ON ARCHIMEDES' LAW

BACKGROUND

Widely held principles of programmed instruction describe the most effective path of learning as one which provides for optimum control over the student's learning behavior. In keeping with that philosophy, it seems clear that when visuals are used, they too should be used in the maintenance of explicit control over the behavior practiced by the student during learning. The selection of stimuli, whether verbal or visual, is such as to elicit appropriate responses and to minimize the adventitious practice of inappropriate or incorrect responses. Instructional advantages of visuals for verbal learning derive from already existing or from newly-formed associations they have with the verbal responses to be acquired (or with verbal responses meaningfully related to these ultimate verbal responses). It is by means of these associations that explicit control can be exercised over the verbal responses that students are encouraged to practice.

A first experiment was designed to explore an instructional approach in which visuals would be employed to maintain control over non-verbal responses. It was an objective of the experiment to determine the extent to which visuals could be used to foster student acquisition of complex concepts without using the visuals to elicit or reinforce explicit verbal responses. An assumption was made that by means of programmed visual discrimination training an alternative method was available to aid students in acquiring complex concepts in science. That is to say, by acquiring the visual discriminations that comprehensively exhaust the events and interrelationships among events in a science demonstration, it should be possible for a student to acquire an understanding of those occurrences. That understanding might consist of and be measured by the student's ability to predict future occurrences of a similar but superficially quite different nature. The ability to make such correct predictions might occur, even though a student was unable to verbalize about the nature of the relationships among events. The acquisition of visual discriminations, if suitably programmed, might, for example, enable a student to predict what will happen to a solid object after it was heated or to predict the reading on a scale if an object is first weighed in air and then weighed while submerged in water. Conceivably, progress through a programmed visual lesson might enable a student to make predictions in a variety of new situations he had not yet encountered. This achievement could serve as evidence of an understanding of the interrelationships among events, whether or not the student was able to verbalize about those interrelationships.

Potentially, a programmed visual lesson might in addition enable a student to state verbally a general proposition concerning what happens to all matter when it is heated or to describe the relationship between the weight of displaced liquids and the apparent loss of weight for submerged objects. The acquisition of visual discriminations in a programmed lesson, thus may serve not only to familiarize the student with what occurs in a given situation following particular events. It may also serve to help students acquire concepts: (a) which describe the nature of the observed relationships among events and (b) which constitute a more fundamental explanation of those events. Acquisition of such concepts could be measured in terms of student predictions about observable events or in terms of his verbalizations about the events or about his explanation of those events.

The experiment briefly described in this interim report seeks to explore the feasibility of programming a solely visual science demonstration that would teach students to understand Archimedes' Law. It further seeks to explore how such visual presentations might be integrated with a verbal presentation in order to maximize student understanding.

DESIGN

Experimental Lessons

Four experimental lessons were developed each of which was designed to fulfill the same objective, namely student understanding of Archimedes' Law. Two of the four versions were entirely visual; the remaining two entirely verbal. The two visual versions were nearly identical in all respects except one. They differed from one another in that students were encouraged to respond actively to one and not to the other. The two verbal versions differed from one another in the same way.

1. Visual Lesson

The visual lesson was programmed in the teaching machine sense. The lesson consisted of sequenced and repetitive demonstrations which required students to make visual discriminations about the occurrences they saw and on the basis of these discriminations to acquire the ability to predict future occurrences. Correct prediction of future occurrences in a criterion situation can, in this lesson, be used to define student understanding of Archimedes' Law.

Briefly summarized, the demonstrations show the relationships between the apparent loss of weight for a submerged object and the weight of the water it displaced. Some of the discriminations required of the students may be more effectively described by means of photographs taken during the recording of the demonstration.

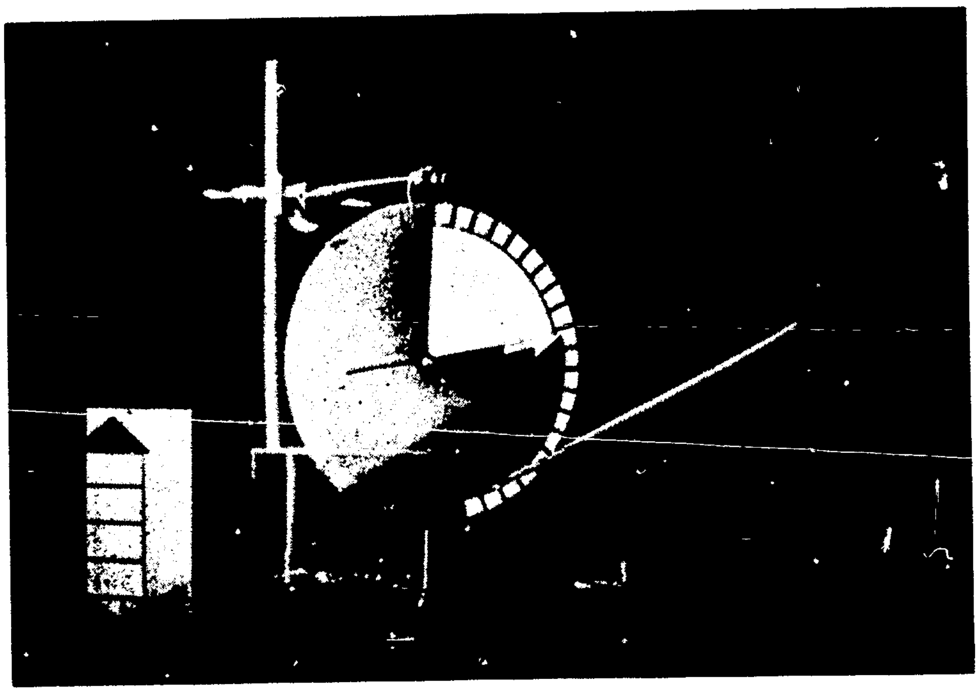


Figure 1

The apparent loss of weight for submerged objects was demonstrated by submerging an object attached to a hanging scale. When the object was submerged, the counterclockwise excursion of the scale pointer indicated the apparent loss of weight (see Fig. 1).

The demonstration was repeated with different sized objects (see Fig. 2). Students were then required to predict what the scale readings would be when new objects were submerged in water. They were presented with a multiple choice situation enabling them to predict which scale reading would result if a new object were submerged. Figures 3 and 4 show scenes indicating how choices were made available. From left to right, the possible choices were: no change, a decrease in scale readings, and finally an increase in scale readings. Following an occasion for student responding, the new object would be submerged and the actual decrease in the scale reading shown. The actual occurrence provided students with feedback as to the correctness of their own responses.

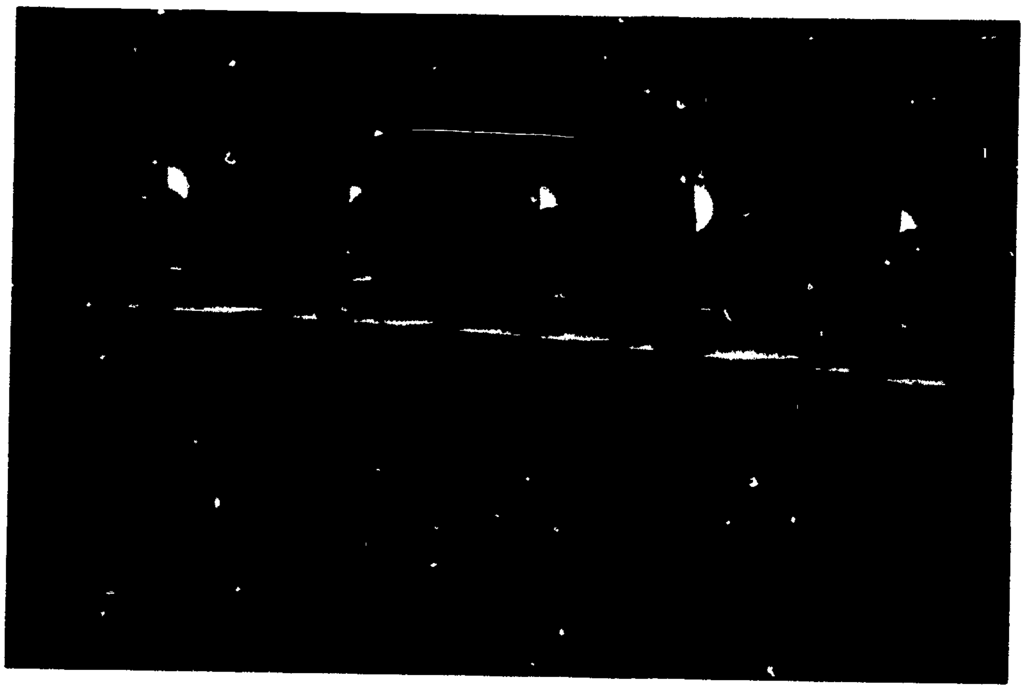


Figure 2

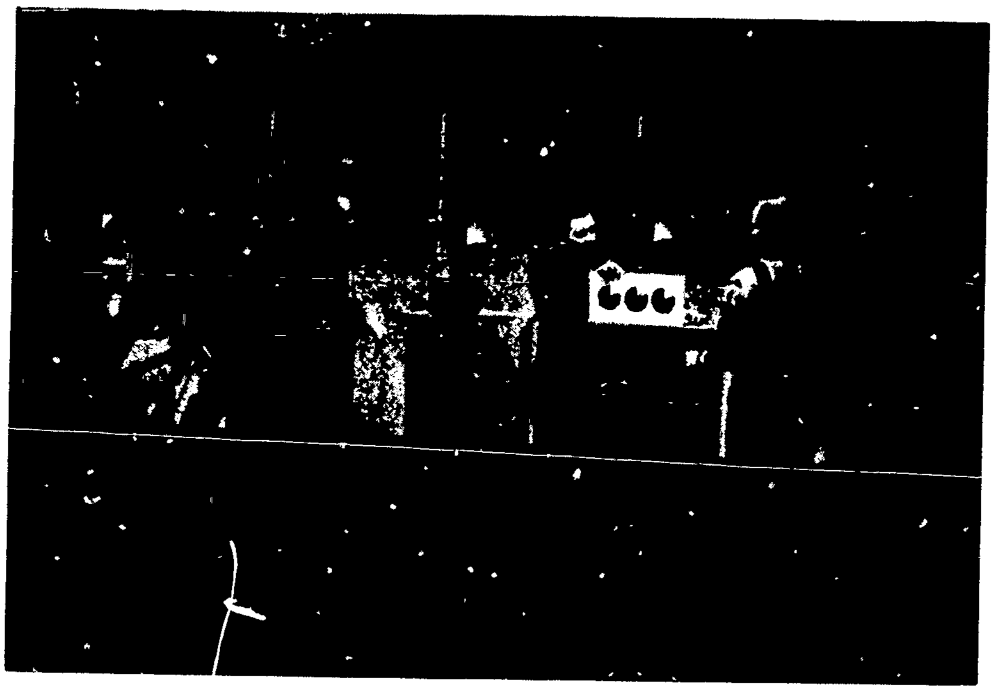


Figure 3

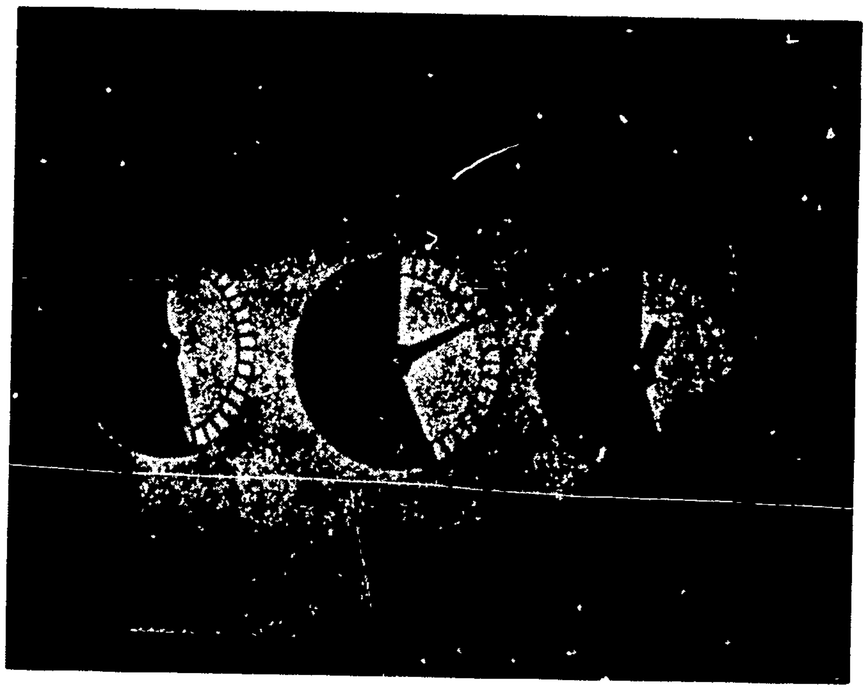


Figure 4

Another set of discriminations built up had to do with the size of an object and the resulting displacement of water (measured by the amount and weight of the overflow). Following repetitions of a demonstration of this interrelationship and the opportunity for students directly to compare object sizes and amounts of overflow (see Fig. 5) the student was expected to predict an amount of overflow, relative to that just demonstrated for a different sized object, which would result from an object not yet used in the demonstration. Figure 6 shows the choices offered students and also shows the identification of the correct response providing them with confirmation as to the actual amount of overflow to be expected for the trial object.

Figure 5

Figure 6

Still another discrimination to be acquired, was that involving the amount and weight of overflow and the magnitude of the buoyant force. Buoyant force had been illustrated analogously in prior sequences by a flashing arrow. The magnitude of the force was represented by the size of the vector as shown in Figure 7a. Figure 7b shows the instructor presenting two amounts of overflow. As part of the instructional sequence, he would then show the relative difference in buoyant force, or in sub-criterion portions of the lesson he would require students to predict, the relative magnitude of the buoyant force resulting if the amount of overflow was like that found in a second or new beaker. As shown in Figure 8 the relationship between size of object, amount of overflow, and buoyant force was similarly illustrated and provided students with the occasion to predict the relative size of the buoyant force for different sized objects.

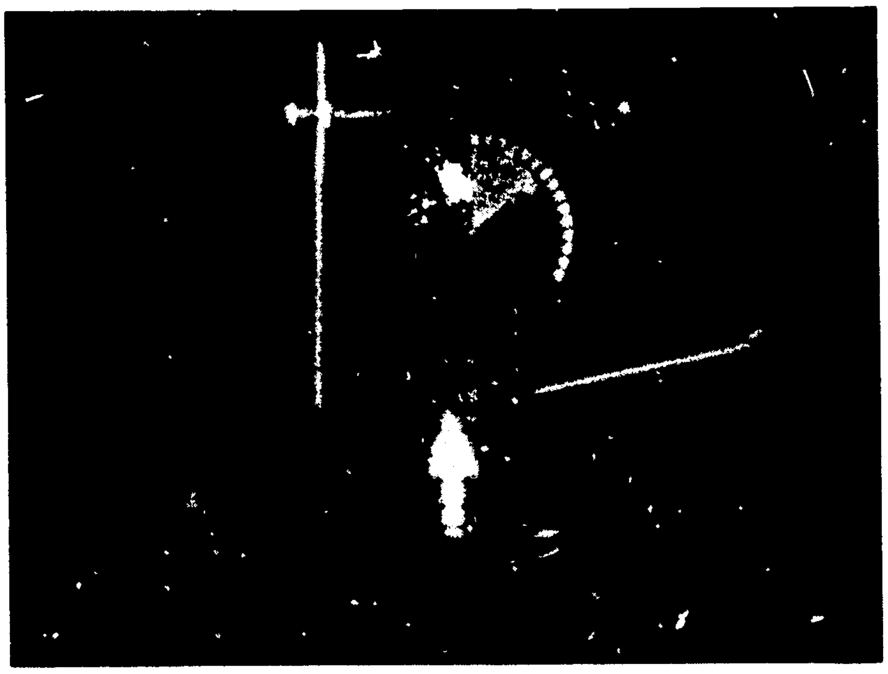


Figure 7a

Figure 7b

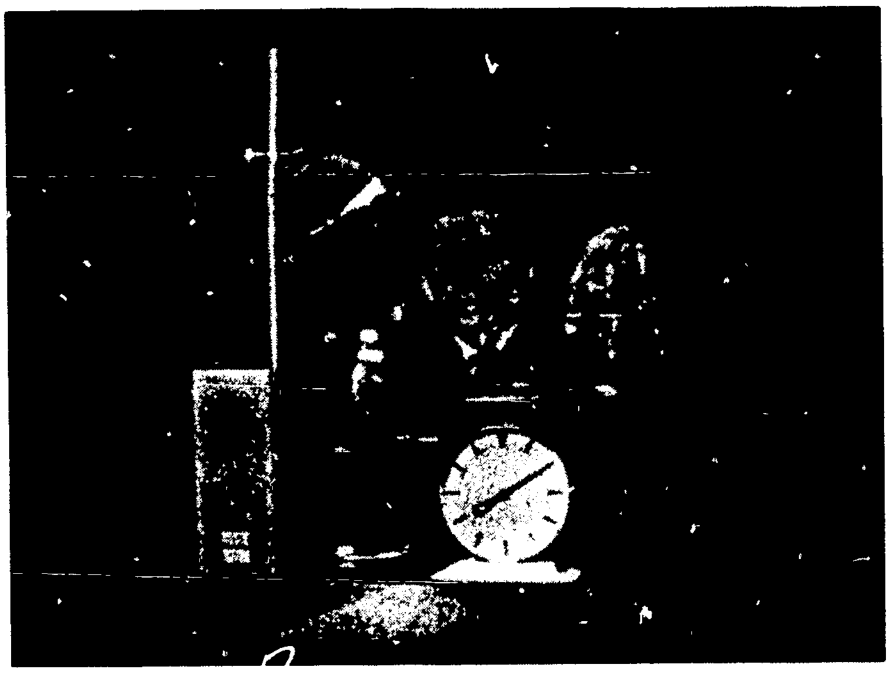
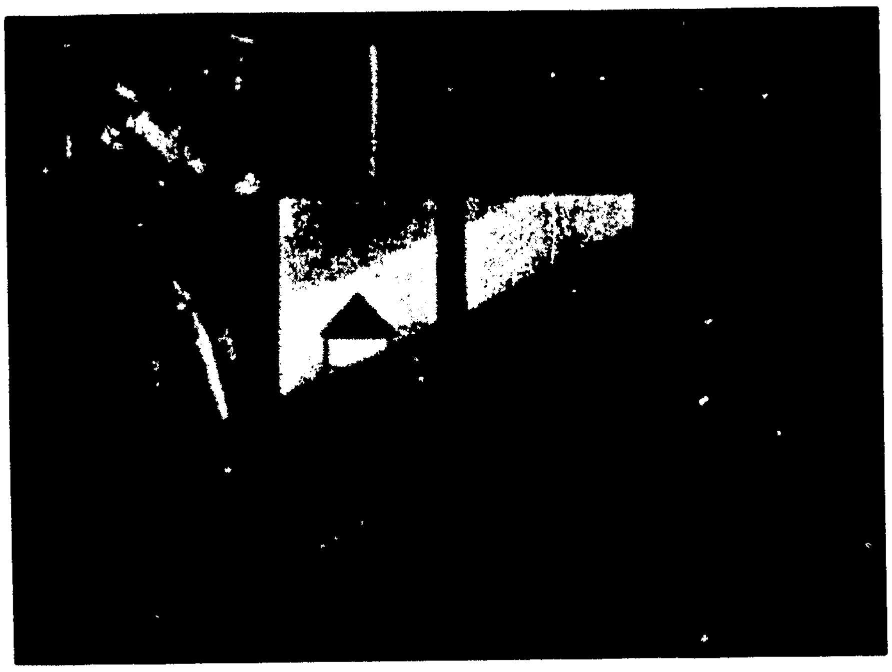


Figure 8

Similar discriminations were built up throughout the entire lesson until all the relevant relationships involved in Archimedes' Law, as described in the lesson objectives, were covered. In later instructional sequences, students were expected not only to select the correct answer from among choices, they were also expected to construct responses. For example, they were required, having been shown the weight of the overflow, to indicate the magnitude of the buoyant force for a particular submerged object.



As shown in Figure 9, the instructor illustrates how they are to indicate their answer. If they thought the buoyant force was of a two-unit magnitude, they were instructed to cross-out two units on their response forms. (The pointer on the dietary scale indicates that the overflow in this example weighed six units. The correct response, thus, would consist of crossing out six units on the vector.)

Figure 9

Students had response forms which, in the case of multiple choice responding, paralleled the choices presented on the screen. Constructed responses were made by marking X's against or circling appropriate scale values.

The visual lesson was prepared so as to enable students to respond appropriately in a visual criterion situation, namely, being able to identify the identity in values for the weight of the overflow, the magnitude of the buoyant force, and the magnitude of the apparent loss of weight. The lesson was programmed and recorded on tape. It was then shown to six trial subjects similar in age and background as those who would participate in the experiment proper. This tryout was for the purpose of determining the error rate in student responding. Based on the results of this tryout procedure, a second and a third version were prepared and recorded. The third and final version produced a relatively low average error rate of 10% and was retained for the experiment. This version was approximately 45 minutes in duration, containing those sequences which on the basis of the pre-test were judged necessary to bring students up to criterion performance.

It should be pointed out that although the lesson has been described as a solely visual lesson, words were used at various strategic places. They were used primarily to encourage and direct student responding. They were in no sense designed to cue particular responses. The instructor, following a sequence of actions, might say: "If I do it to this one, what will it be like here; will it be like this, like this, or like this?". During the spoken phrases "like this, etc." a stage hand might point to three different readings on the same scale or to three different scale models each with a different reading. Thus, although it is evident that asking a question tended to direct the kinds of response that would be made, it did not cue the actual, correct response. Cuing of correct responses was accomplished by the sequence of visual events.

The alternate version of the visual lesson consisted of the same sequences as just described. However, they did not provide occasions for student responding nor did they offer alternative possible outcomes. Students watching this version merely saw the correct relationships among events visually demonstrated. They were not given the opportunity to predict outcomes for new and as yet undemonstrated events. To make up for the extra time that was required by and that might possibly favor the group watching the original version, some strategic sequences were repeated. This alternate version was approximately 35 minutes in duration.

2. Verbal Lesson

A verbal lesson was prepared based on the same lesson objectives that guided the preparation of the visual lesson. That is to say, the facts and concepts having to do with Archimedes' Law were spelled out in behavioral terms and guided the preparation of both versions of the lesson. The verbal lesson was programmed and tried out several times. During these tryouts students were allowed to pace themselves and careful records were kept of the amount of time students required to complete particular response segments. Since the TV presentation would be paced and a fixed time allotted to each response segment, these records were later used as a basis for determining the appropriate duration for presenting each of these response segments.

Following a tryout and revision resulting in a programmed verbal lesson that yielded an average error rate of approximately 10%, the lesson was recorded on video-tape (see Figs. 10 and 11).

Figure 10

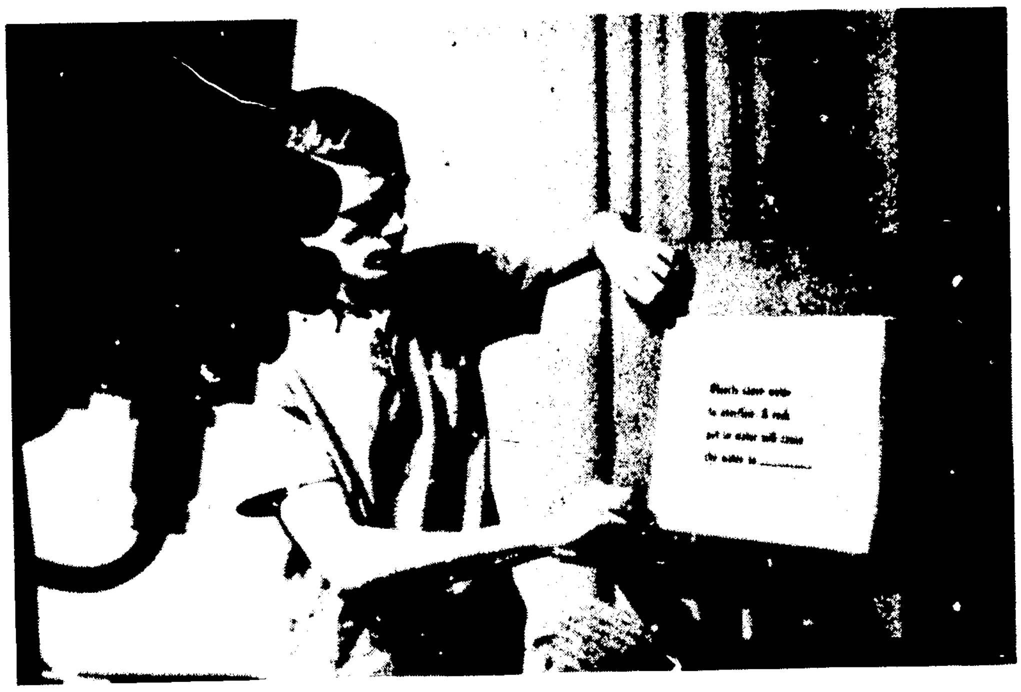


Figure 11

The lesson consisted of sentences containing blanks which students were required to fill in (on their work forms). Following the allotted duration for each sentence, the correct response in bold print and in another color was popped on in the blank slot (see Figs. 12 and 13). After sufficient time for students to read the correct response, the card was pulled revealing the next card containing a sentence with a blank space to be filled in. Although this was essentially a visual presentation of printed material, the instructor did systematically call out the numbers of the pages students were supposed to be working on and also called their attention to the screen when the response was being presented on the screen. This served two functions. It tended to preclude an entirely soundless and potentially monotonous presentation. It also served to prepare students for changes in the presentation and thus could aid all students in keeping pace with the presentation.

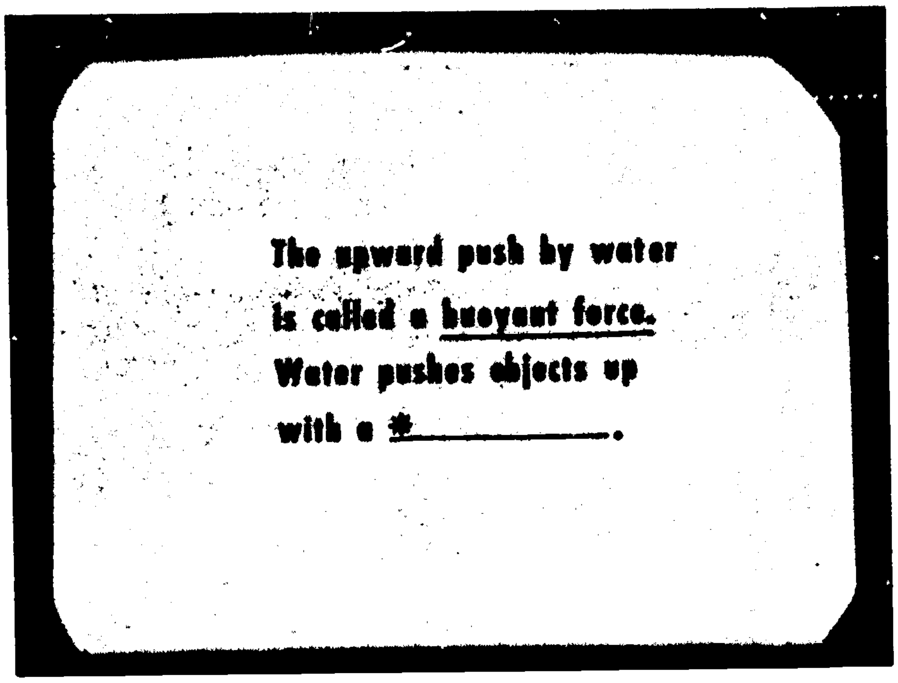


Figure 12

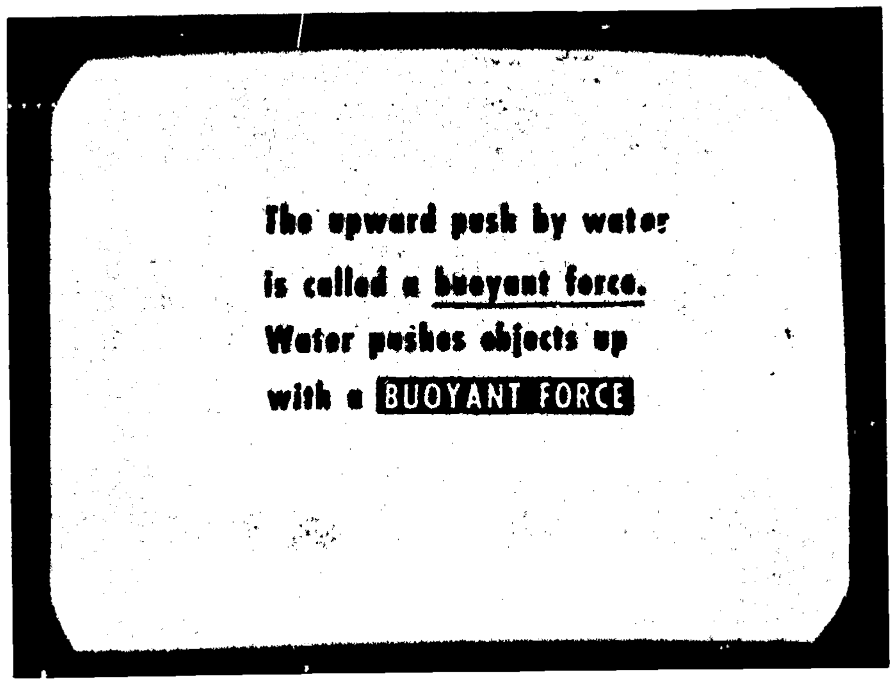


Figure 13

The verbal lesson was almost entirely verbal in nature. Occasionally there were brief camera shots of an object on a scale or an object submerged under water. These shots were very brief and did not include any action. They served merely to facilitate the verbal programming by precluding the need for additional, and possibly needless, time-consuming sentences. The entire verbal lesson lasted approximately one hour.

The alternate version of the verbal lesson provided students no occasion for responding. They were shown only sentences with blanks already filled in (as in Fig. 13). Each sentence was allotted approximately as much time as was allotted for students to respond in the original version. The time allotted for popping on the correct answers was eliminated. In general, time for each sentence was reduced, primarily because the durations allotted for responding would have been excessive from the point of view of maintaining student attention and interest (as pre-testing had indicated). This version of the lesson lasted approximately 40 minutes.

Design and Experimental Variables

The four experimental lessons were combined and compared in various ways to answer a number of research questions. They were the following eight experimental groups as summarized in Table 1. Except for groups seven and eight, all groups were given two versions of the lesson on Archimedes' Law, but in different orders and combinations.

TABLE 1

Design of Experiment

	Active Response			
	Group 1	Group 2	Group 3	Group 4
presentation 1	Verbal Lesson	Verbal Lesson	Visual Lesson	Visual Lesson
presentation 2	Verbal Lesson	Visual Lesson	Visual Lesson	Verbal Lesson

	No Active Response		Active Response	
	Group 5	Group 6	Group 7	Group 8
presentation 1	Visual Lesson	Verbal Lesson	Visual Lesson	Verbal Lesson
presentation 2	Verbal Lesson	Visual Lesson		

This design makes it possible to investigate the following research problems: (a) the feasibility of programming visual demonstrations; (b) the relative effectiveness of verbal and visual programs; (c) the optimal order of presenting both verbal and visual programs; and (d) the effect on learning of active vs. passive responding to verbal and visual programs. A comparison of achievement test results administered to the various groups included in the experimental design before, immediately after, and on a delayed basis permits an exploration of the effects on learning of the following variables:

- - active responding vs. no active responding
- - visual vs. verbal modes of presentation
- - order of presentation
- - time of testing

Alternate forms of an achievement test were developed to cover all the material specified in the statement of lesson objectives. The tests were pretested and items revised based on an administration to a class which would not participate in the experiment but which was similar in grade level to the classes that would participate. The basic difference between them was that the pre-test group had already received instruction in Archimedes' Law. Item difficulty level and item discriminative power was based on an analysis of their test results. Items were revised based on these results.

The achievement test was divided into two parts: a verbal part and a visual part. The verbal part of the test consisted of multiple choice questions about concepts relating to Archimedes' Law, including some numerical computation. The visual part of the test consisted of pictorial representations of objects, scales, beakers containing displaced liquid, etc. Problems, although verbally stated, depended for their solution on students visually perceiving objective facts and relationships. The problems approximated those with which students had to deal during the visual program and with which they might have to deal in the physical world.

Subjects

Subjects were eighth grade students drawn from classes which regularly watch junior high school science televised over station WQED in Pittsburgh. Although it was not feasible to assign students from each class randomly across all eight experimental conditions, it was possible to make random assignments to sets of two experimental conditions. Students from each class were matched for IQ and pre-test scores on the achievement test. One member of each matched pair was assigned at random to one condition in a set of experimental conditions (for example, to group 1) and the other member to the second condition (for example, to group 2). The sets to which such random assignments were made consisted of: (a) groups 1 & 2; (b) groups 3 & 4; (c) groups 5 & 6; and (d) groups 7 & 8.

Twenty-five students were assigned to each of the eight experimental groups.

Procedure

Two weeks prior to the date in which he would participate in an experiment, each student took an achievement test to determine the level of his prior knowledge of the subject matter. Aptitude tests were also administered to students prior to the experiment at the administrative convenience of the schools. The Aptitude Promise Test published by the Psychological Corporation was used to measure verbal ability and abstract reasoning skills, which were judged to be related to performance in the verbal and visual versions of the lesson respectively. Students were then brought into the studio of WQED on the day of the experiment (conducted on two separate Saturdays) to view the experimental lessons over closed circuit television. One group of subjects viewed one version of the lesson on monitors in one studio, while a second group viewed another version (according to which experimental group they belonged) in another studio (see Figs. 14 and 15). Students then took one form of the achievement test. Following a ten-minute break, students entered the alternate studio to receive their second lesson (either a repetition of the first or another version as per the design of the experiment). The alternate form of the test was administered following the second version of the lesson. Two weeks later the first form of the test was administered once again, this time in the schools.

Figure 14

Figure 15

RESULTS

Partial analyses of the data have been completed providing preliminary results bearing on the following research issues: (1) the relative effectiveness of visual and verbal programs; (2) the optimal order of visual and verbal programs; and (3) the relative effectiveness of active and passive versions of visual and verbal programs.

1. Comparison of Visual and Verbal Programs

The results of an achievement test administered to students immediately after seeing either the visual program or the verbal program were analyzed to determine whether students made a significant gain in their knowledge of Archimedes' Law. A separate gains analysis (pre-test minus post-test scores) was performed for students who had only seen the visual program. A similar analysis was performed for students who had only seen the verbal program.

a. Visual program: Students who watched and responded to the "active response" visual program made an average gain of 5.8 points on the total test score. (The total possible score on the test was 38 points, with students averaging approximately

50% correct on the pre-test.) A t-test for difference scores showed this gain to be significant at the .001 level of significance. Table 1 summarizes this result.

b. Verbal program: Students who watched and responded to the "active response" verbal program made an average gain of 5.12 points on the total test score. A t-test for difference scores showed this also to be a significant gain. This result is also summarized in Table 1.

TABLE 1

Gains Analysis of Total Score For Visual and Verbal Programs

	Visual Program		Verbal Program
Pre-test average score:	20.1	Pre-test average score:	20.7
Post-test average score:	25.9	Post-test average score:	25.8
Mean gain	5.8		5.12
S.D.	4.37		5.04
t	8.4		6.4
d.f.	39		39
P	.001***		.001***

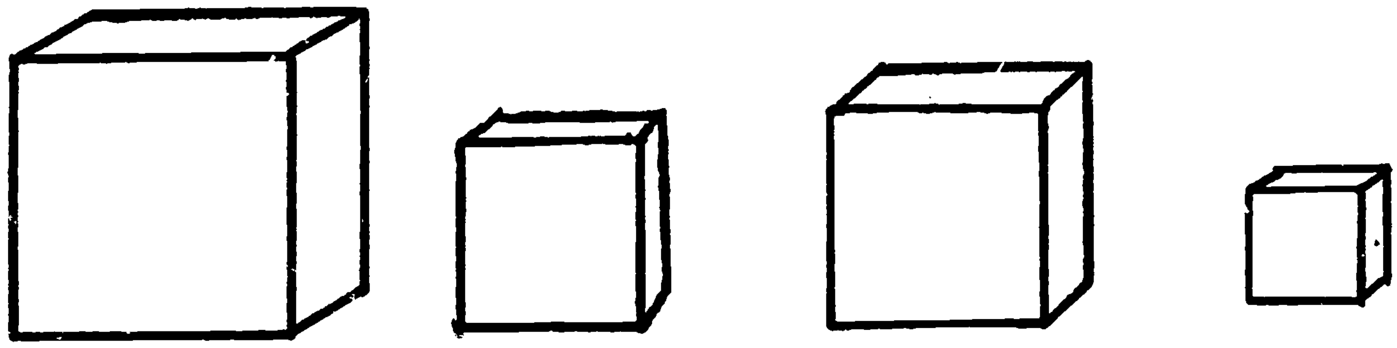
***significance at the .1 percent level

c. Visual vs. verbal programs: There were no significant differences in gains on total test scores between students who had watched the visual program and students who had watched the verbal program. After receiving instruction on Archimedes' Law, both groups made gains on the achievement test of approximately 25%. Significant differences were found between visual and verbal groups, however, when the visual and verbal portions of the achievement test were analyzed separately.

The visual test consisted of pictorial items about which the student was required to make discriminations, which if appropriately made, would indicate that he understood Archimedes' Law. Figure 16 presents a sample visual test item.

Figure 16

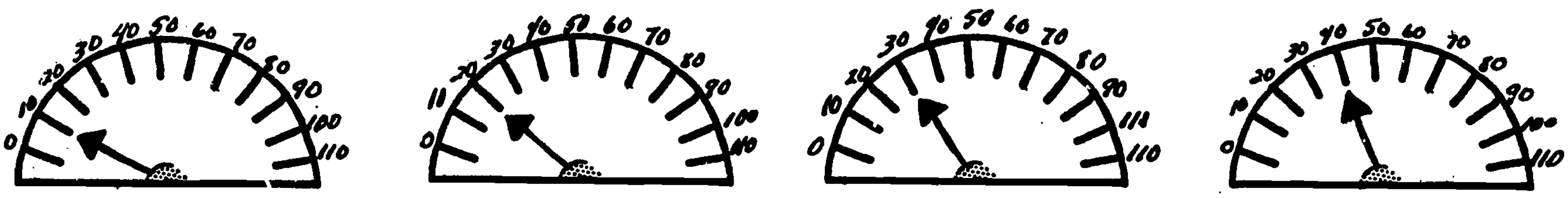
12. These four objects are each put into a separate tank of water.



A.
Amount of Force ________ ________ ________ ________

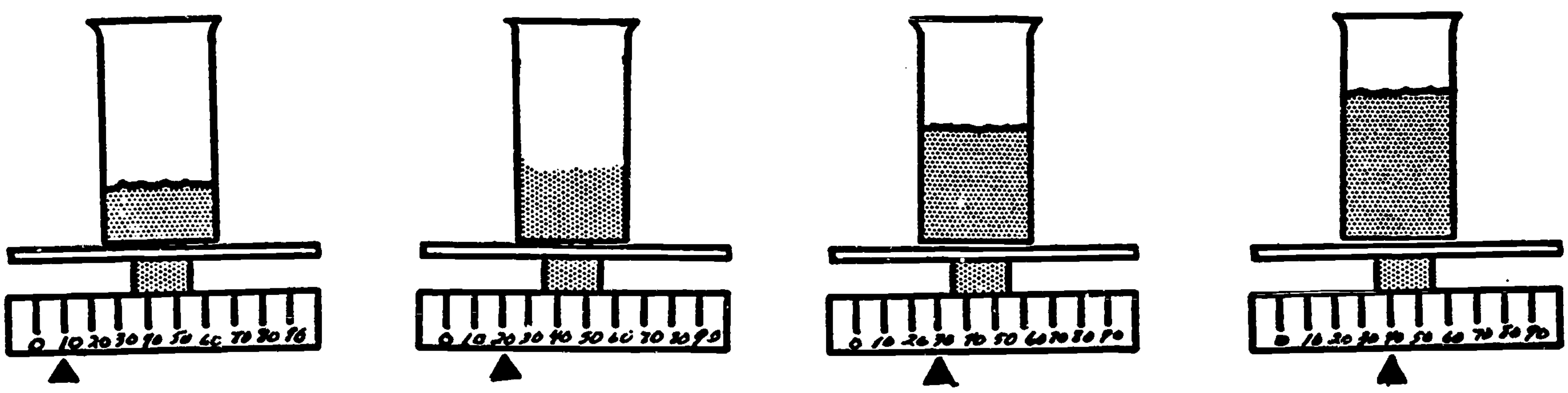
B.
Weight of Overflow ________ ________ ________ ________

Each of these scales indicates the amount of push the water exerts on each of the above objects.



Which force goes with which object? Write in the correct amount of force below each object in row A.

Each of these scales indicates the weight of the overflow caused by each object.



Which overflow goes with which object? Write in the correct weight of the overflow for each object in row B.

Table 2 summarizes the performance on the visual test for students who had received the visual program and also for students who had received the verbal program. (The total possible score on the visual test was 16.)

TABLE 2

Gains Analysis of VISUAL TEST Scores
For Visual and Verbal Programs

	Verbal Program	Visual Program
Average score on pre-test	9.6	9.1
Average score on post-test	10.5	11.5
Average gain	.95*	2.35*
S.D.	2.78	2.95

*The difference in gains between students receiving the visual program and students receiving the verbal program was significant at the 5 percent level.

An analysis of variance showed the difference in gains on the visual test between the verbal program and visual program groups to be significant at the 5% level, with the group of students who had watched the visual program outperforming the group of students who had watched the verbal program (F=4.55 for 1/76 d.f.). Students who had watched the verbal program made a gain of only 10% on the visual test as against a gain of approximately 25% made by the students who had watched the visual program.

On the verbal test, no overall significant difference was found between visual and verbal groups. An analysis of variance did, however, show a significant interaction between type of program watched and IQ. Table 3 summerizes the gains on the verbal test made by high and low IQ students who watched either the visual or verbal programs. (The number of points possible on the verbal test was 22.)

TABLE 3

Gains Analysis of VERBAL TEST Scores For High and Low IQ Groups Watching either Visual or Verbal Programs

	High IQ		Low IQ	
	Verbal Program	Visual Program	Verbal Program	Visual Program
Average Pre-test score	13.0	13.2	9.3	8.8
Average Post-test score	17.8	15.7	12.8	13.2
Average gain	4.8	2.5	3.55	4.4
S.D.	3.3	2.5	3.7	3.1

The analysis of variance of the interaction between IQ and type of program watched was significant at the 5% level (F=4.56 with d.f. 1/76). Subsequent t-tests performed separately for the high and low IQ groups indicated that only for the high IQ group was the difference between verbal and visual groups significant (t=2.42 at 19 d.f.; P=.03*). Among high IQ students, those who watched the verbal program made a significantly higher gain in achievement (approximately 37%) than did those who had watched the visual program (approximately 19%).

2. Comparison of Order of Presentation

The analyses just summarized were for results of tests administered after students had watched either a visual or a verbal version of the lesson on Archimedes' Law. Students during the course of the entire experiment ultimately saw both verbal and visual versions of the lesson on Archimedes' Law. One group saw the verbal version first followed by the visual version. A second group also saw both versions but in the reverse order. A comparison of these two groups which saw both versions of the lesson but in different orders reveals that students who saw the visual lesson first followed by the verbal version made significantly greater gains on the achievement tests administered at the conclusion of both versions (F=5.75 for 1/20 d.f.; P=.05*). Table 4 summarizes the results showing the superiority of the visual/verbal order. Students who had received the lessons in the visual/verbal order made a gain of approximately 40% over their initial level of knowledge as opposed to only 22% for students who had received the lessons in the reverse order.

TABLE 4

Gains Analysis of TOTAL TEST Scores For Groups Watching both Visual and Verbal Lessons in Different Orders

	Visual/Verbal Order	Verbal/Visual Order
Pre-test score	18.9	20.1
Immediate post-test score	26.5	24.7
Average gain	7.57*	4.52*
S.D.	4.7	4.8

*The difference in gains between the groups watching the lessons in different orders was significant at the 5 percent level.

3. Comparison of Active and Passive Versions of the Visual/Verbal Order

There were active and passive versions of both the visual and the verbal lessons. A comparison could thus be made for students receiving the lessons in the visual/verbal order but in either active or passive versions. Tables 5, 6, and 7 show that on tests administered: (a) immediately following the visual version; (b) immediately following the combined visual/verbal presentation; and (c) on a delayed basis two weeks later -- students who watched and responded to the active response versions averaged higher on a verbal test (17-point test). The differences in gains between the active response group and the passive group were statistically significant, as revealed by an analysis of variance: for the test immediately following the visual lesson (P=.05*); for the delayed test (P=.01**); but not for the immediate post-test. On the verbal items of the delayed test, the active response group made gains of approximately 65% as against only 20% made by the passive response group.

TABLE 5

Gains Analysis of VERBAL TEST Administered after the Visual Lesson to Active and Passive Response Groups

	Visual/Verbal Order	
	Active Response Group	Passive Response Group
Pre-test mean	6.61	7.89
Post-test mean	10.19	9.18
Mean gain	3.55*	1.2*
S.D.	3.3	2.8

*The difference between active and passive response groups was significant at the 5 percent level.

TABLE 6

Gains Analysis of VERBAL TEST Administered Immediately after Both the Visual/Verbal Lessons to Active and Passive Response Groups

	Visual/Verbal Order	
	Active Response Group	Passive Response Group
Pre-test mean	6.61	7.89
Post-test mean	11.42	11.14
Mean gain	4.78	3.15
S.D.	3.00	2.36

TABLE 7

Gains Analysis of VERBAL TEST Administered Two Weeks after Receiving Visual/Verbal Lessons to Active and Passive Response Groups

	Visual/Verbal Order	
	Active Response Group	Passive Response Group
Pre-test mean	6.61	7.89
Post-test mean	10.98	9.58
Mean gain	4.3**	1.6**
S.D.	3.07	2.57

**The difference between active and passive response groups was significant at the 1 percent level.

DISCUSSION

The results of the present experiment indicate that students can learn effectively from programmed verbal materials presented over TV. This is in keeping with previous findings of Gropper and Lumsdaine (4) who found that group instruction over TV can be made more effective by programming lessons and requiring active student responding. The results of the present experiment also reveal the feasibility and effectiveness of programming non-verbal, visual lessons. Students who practiced appropriate visual discriminations during a programmed visual lesson made significant gains in their knowledge and understanding of Archimedes' Law. It thus appears that by suitably programming visual demonstrations and by requiring students to make visual discriminations based on those demonstrations, formation of concepts can be stimulated. The visual programs employed in this experiment not only enabled students to make correct discriminations during instruction and afterwards in the criterion situation but they also enabled students to verbalize about the principles covered by the lesson. That students would be able to transfer the discriminations acquired during instruction to the criterion situation is not altogether surprising. But that they should in the criterion situation also be able to verbalize the concepts explaining the programmed visual events would not necessarily have been predicted. Whether or not these findings are generalizable to the use of other visual demonstrations may be a function of the visual events employed and the referents they are supposed to illustrate. Further visual programming and more systematic manipulation of dimensions of representation with other topics will be necessary for generalizable conclusions about the potentialities and limits of visual programming.

In comparing the relative effectiveness of the visual program and the verbal program, it was found that the visual program better prepared students for performance on the visual test. Practicing visual discriminations during instruction thus enabled students adequately to make similar discriminations on the criterion test. Since the kinds of discriminations required by the test are in turn similar to behaviors typically required in the ultimate criterion situation, namely interpretation of real world physical events, it would appear that the kinds of behavior students practiced during the visual program may be particularly beneficial in preparing them for observing and explaining events in the real world. On the basis of performance on the criterion test, the visual program better prepared students for this type of performance than did the verbal program.

On verbal tests measuring student ability to verbalize about Archimedes' Law, no significant difference was found between the effectiveness of the visual and verbal programs. There was, however, a significant interaction between type of program and IQ level. Among high IQ students, those who had watched the verbal program were significantly better able to verbalize about the relationships and concepts involved in Archimedes' Law than were students who had watched the visual program. Among low IQ students, the reverse finding was found. Although this latter finding was not statistically significant, there was a tendency for the low IQ students to be able to take better advantage of the visual program than of the verbal program. On the basis of these preliminary findings, further exploration of different modes of instruction that can accommodate different patterns of student ability is clearly indicated.

In general, it is suggested that the meaningfulness of demonstrational events (by which is meant the nature and strength of the verbal associations with those events) will determine the ease with which concepts will be acquired on the basis of visual discrimination training. The weaker the associative strength between demonstrational events and verbal responses (as for example in the case of analogous representation), the less readily will those events adequately facilitate the acquisition of appropriate concepts. In the present experiment, it proved more difficult (as measured by student ability to acquire the appropriate concepts) to program visual sequences using analogous rather than direct or indirect representations. The relationship between object size and resulting amount of liquid displacement could readily be shown directly and was easily discriminated by students. The use of a vector, an analogous representation, for the buoyant force of water, less easily led to student understanding. This differential effectiveness, it is suggested, is due to the higher associative strength (with verbal responses) for direct than for analogous representations.

It should, perhaps, be reiterated at this point that students saw both visual and verbal programs. Each complete program was viewed before students saw the other. The order in which programs were viewed made a significant difference for the gains in measured achievement that students made. Students who saw the visual program <u>before</u> being exposed to the verbal program outperformed those who saw the visual program <u>after</u> seeing the verbal program. Acquiring visual discriminations about demonstrated physical events appears to prepare students to be better able to benefit from a verbal explanation of those events when the acquisition of the discrimination precedes rather than follows the explanation. The verbal explanation is perhaps better understood only after the events and relationship among events of the demonstration are adequately discriminated. Thorough familiarity with concrete events and their interrelationships may, thus, better prepare students for the more abstract verbal description and explanation which follows.

It would appear that, based on the findings of this experiment, demonstration should precede explanation. <u>But, it should be noted that it is a demonstration of a particular kind, namely, one in which discriminations about demonstrational events and their interrelationships are acquired</u>. It should also be noted that the demonstrations used in this study were complete, self-contained demonstrations designed to facilitate the acquisition of all the significant concepts covered by lesson objectives. They were not like conventional demonstrations which merely accompany a verbal presentation or are accompanied by a verbal commentary.

There seems to be little reason why in conventional lessons short demonstrational sequences could not be interspersed with verbal material, with alternating visual discrimination and verbal response sequences until all lesson topics are adequately covered.

A further significant finding in this experiment was that among those who viewed the programmed lessons in the visual/verbal order, gains in knowledge were better retained by those who made active, overt responses than by those who saw comparable lessons which did not require such responding. This is fully in keeping with findings from research on participation techniques employed in teaching machines or filmed instruction.

CONCLUSION

CONCLUSION

Two contrasting approaches to the use of visuals in verbal-conceptual learning have been described. One approach, described in the introductory section to this interim report, called for the use of visuals in cuing and reinforcing verbal responses. Explicit verbal responses can be systematically brought under the control of visual stimuli thereby building up a verbal-conceptual repertoire. This is accomplished by student practice of appropriate verbal responses.

A second approach, briefly delineated in the experiment just described, calls for student practice of visual discriminations of events and their interrelationships during the course of visual demonstrations as a means of facilitating the acquisition of concepts. Visuals can be programmed or manipulated in such a way that control is exercised over the visual discriminations to be practiced. In this particular experiment, the visual discriminations practiced and the sequence in which they were practiced led to student acquisition of the concepts and principles involved in Archimedes' Law. On the basis of this programmed visual lesson, not only did students become able to discriminate among events in the demonstration, but they also acquired the concepts and principles that explained the interrelationships among those events. Student ability to verbalize about those events was evidence of this latter acquisition.

In conventional uses of demonstrations, demonstrations either precede, follow, or accompany a verbal explanation. They may also contain verbal descriptions of events and their interrelationships. Rarely, however, are students themselves required to learn how to describe the events of a demonstration in verbal terms or to acquire discriminations about the same events. Typically, the demonstration is used to illustrate (with varying degrees of literalness) what has been stated verbally. The events of the demonstration may also be described verbally, and this may be followed by a verbal presentation which attempts to make the connection between the visual and verbal portions of the demonstration. Under any of these conditions, with no opportunity for students to practice verbal responses which would label the events and their interrelationships or with no opportunity for them to practice the discriminations that would serve a similar "labeling" function, students may fail to make the proper connection between verbal explanation and visual illustration.

The requirements for an optimum demonstration, that is, whether verbal responses or visual discrimination or some combination of the two are to be practiced, may be a function of: (a) the nature of instructional objectives; (b) the characteristics of the referents to be represented; and (c) the type of visual representation employed. The experiment described in this interim report represents a first attempt to program a visual demonstration and, as such, the variables just listed were not systematically treated. Further analytic study of the influence that the dimension of literalness of representation has on the effectiveness of either of the two instructional approaches is particularly indicated. Similar studies with different objectives, e.g., whether the events of a demonstration are to be recalled or whether they are to be explained, and with different lesson content are also indicated.

Future plans for the remainder of this project call for, within time and budgetary limitations, consideration of one or more of the following problems: methods of visual programming; the relationships between kinds of visual discriminations practiced and the concepts they can generate; comparative effectiveness of verbal or visual stimuli used to cue and reinforce responses.

Effective instruction can result from the optimum use of integrated visual and verbal presentations. Empirical answers to the kinds of questions introduced here are needed for the development of an applied technology of such integrated presentations.

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